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Is Surabaya being planned as a low-risk city?

A case study on the effect of urban spatial plans in the Kedurus catchment area on flash flood risk reduction in Surabaya

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Abstract: Spatial plans are key instruments in directing future developments and reducing a city's flash flood risk. This study conducts a surface runoff simulation using SWAT analysis in the Kedurus catchment area. SWAT analysis is a hydrological analysis to measure surface runoff from precipitation with consideration of land uses, soil types, climatic data, topography and related infrastructure systems. Based on the simulation, four sub-catchment areas are currently experiencing flash flooding. Surabaya's detailed spatial plan (RDTR) could reduce the total flood volume in the city by fifty-one per cent if all measures (drainage and other infrastructures) in the plan are implemented successfully. Nevertheless, the implementation of the measures is still questionable due to limited budget and land acquisition. In the case of plan failure, the planned developments will cause higher surface runoff, putting Surabaya is at higher risk of flooding. Therefore, Surabaya needs to diversify its flash flood risk reduction approach to ensure that the plan will achieve a low-risk city in the future.

1. INTRODUCTION

Developments should improve the economic, social, and cultural conditions of people, communities, and societies. Todaro and Smith (2005) stated that there are three main goals of development, i.e. fulfilling basic needs, increasing freedom of choice (e.g. economic and social choices) and increasing people's self-esteem. To achieve those goals, there should be an integration of multiple aspects of life such as in the framework of sustainable development (Wheeler & Beatley, 2014). Furthermore, sustainable development concerns not only the economic, institutional, social, and environmental aspects but also resilience. The New Urban Agenda highlights the importance of the aspect of resilience in responding to unpredictable and intensified future disasters as one of the key challenges in future development (Satterthwaite, 2016). Spatial plans are important in ensuring the optimal allocation and use of limited resources including land. As such, spatial plans are crucial in achieving the best development outputs. Unfortunately, in many cases, the lack of regulations and effective planning leads to the adverse impacts of developments which could put cities at a high risk and result in the deterioration of living conditions.

Intensive developments convert non-built-up areas into built-up areas, thereby increasing runoff. Meanwhile, the current drainage system in cities may be unable to accommodate the increase in surface runoff, thereby resulting in flooding. Flooding is a major concern for planners in creating a low-risk city. Flood risks are further increased due to other complex problems such as the impacts of climate change in Indonesia (Hidayat & Harianto, 2008) and community behaviour such as uncontrolled land conversion (Kurniawan & Sudjoko, 2018). Therefore, this highlights the urgency to simulate the predicted effect of spatial planning on flood reduction which can help evaluate the effectiveness of plans in creating a low-risk city.

1.1 Spatial Planning System

In Indonesia, there are two main spatial planning products, the regional plan and the detailed plan which are based on the national spatial planning Act No. 26 of 2006. The regional plan is called *Rencana Tata Ruang Wilayah* (RTRW) and it functions as the strategic spatial plan for regulating key and major developments for the next twenty years. The regional plan is then further detailed by the detailed plan or *Rencana Rinci.* The detailed plan contains more focused and specific regulations on spatial and building developments. Specifically, on the municipal level, the *Rencana Detail Tata Ruang* (RDTR, hereafter referred to as the detailed plan) is used as the main reference for building permits as stated in the Regulation of the Ministry of Public Works No. 20 of 2011, then revised by the Regulation of the Ministry of Agrarian Affairs and Spatial Planning No. 16 of 2018. Consequently, every building constructed in Indonesia should adhere to the municipal arrangement as stipulated in the detailed plan.

In 2014, Surabaya enacted the Surabaya Regional Plan 2012-2032. As for the detailed plan, currently, Surabaya City has successfully enacted the plan under the Local Regulation No. 8 in 2018, around December 2018. For the timeframe of this paper, a draft from July 2018 is the main material for the analysis process. The draft at the time was nearly to be legalized, indicating that the material is to be similar to the actual plan.

The main concern of the detailed plan is allocating land for specific activities in a land parcel (e.g. residential, commercial and green open space). Furthermore, the detailed plan also regulates certain building regulations such as the floor area ratio (FAR) and green area ratio (GAR) for every parcel. In the detailed plan, the land use allocation, building regulations, drainage system and infrastructure investments related to flood reduction are the key spatial planning instruments. Since the detailed plan is valid for twenty years, it is important to assess these plans for their effectiveness in reducing flooding. Plans that are ineffective in solving problems will only intensify the flooding, thereby putting city-dwellers at high risk. One of the ways a low-risk city can be created is through the use of a rational approach, where the effects of the four key instruments in spatial planning (land use plans, building regulations, drainage systems, and other infrastructure) on flood reduction are assessed. This rational approach is one of the applications of intelligent planning.

1.2 Problem and Objective Statements

Flash flooding is considered as one of the four main disasters in Surabaya City, as stated in the Surabaya Medium-Term Development Plan (2018). Low-scale flooding commonly occurs in many parts of Surabaya with only 10-20 cm of inundation for one to two hours encompassing the central part to the eastern and northern parts of Surabaya. A different situation is experienced in some areas in the western and southern parts of Surabaya including the Wiyung District. Wiyung, which is part of the Kedurus catchment area, experienced higher levels of flooding compared to the rest of Surabaya with an inundation of about 50 cm up to more than 1 m on February 24th, 2016 (Fajerial, 2016; Lestari, 2016). The flash flood had major impacts on the city dwellers, such as inundated roads, thereby making the Wiyung area inaccessible during the flood (Fajerial, 2016).

This paper aims to assess the effectiveness of spatial planning in reducing flash flooding. This assessment can ensure that Surabaya's detailed plan in the future will create a low-risk city. The assessment will compare the current surface runoff with the projected runoff based on the land use regulations in the spatial plan. The study will also compare the current situation with the planned approaches in the plan aimed at managing runoff. After uncovering the runoff behaviour in the two conditions, the study offers recommendations to achieve the goal of Surabaya as a low-risk city. Hopefully, this recommendation can be used as an input for public policy, particularly for spatial planning in Surabaya, in its review stage.

2. METHODOLOGY

To assess the effectiveness of the plans proposed in the detailed plan, data related to the current situation and the proposed plans for the next twenty years should be compared. This paper will compare data on land use allocation, building regulations, the drainage system, and infrastructure investments related to flash flood reduction in the detailed plan within those two timeframes. The data for the current situation will be drawn from the draft of the Surabaya Detailed Plan (RDTR) 2018-2038, the July 2018 version, while the proposed plans are also collected from the same document, specifically from the planning section.

Planning in the public domain has is a well-known concept by John Friedmann from 1987, indicating that spatial plans are part of public policy. Therefore, the detailed plan should comply with the criteria of public policy i.e. be effective, efficient, adequate, responsive, accurate, and equitable (Dunn, 2000). These criteria are important in ensuring that the proposed plan will be able to reduce flooding. The effectiveness criterion is the main concern of this paper, which asks the main question of "do the proposed plans in Kedurus catchment areas reduce flash flooding effectively?"

In assessing the current surface runoff, the study applies a hydrological model using the Soil & Water Assessment Tool (SWAT) (Neitsch et al., 2005; Yu et al., 2018). A good understanding of hydrological processes is key in developing water resources, especially the connection between rainfall and surface runoff (Amell et al., 2001). A model is crucial in simplifying complex hydrological processes (Wheater, Sorooshian, & Sharma, 2007). Consequently, this study uses the SWAT hydrology model. The model is relevant for undeveloped areas that will likely be developed in the near future, such as the Kedurus catchment area. Kuhn (2014) suggested that an appropriate case study to apply the SWAT model would comprise more than fifty per cent non-built-up areas. Moreover, SWAT can be used to simulate the hydrological process of a watershed at various spatial and temporal scales (Francesconi et al., 2016).

The model is built using ArcSWAT. This ArcGIS-ArcView extension is an interface for SWAT. A downloadable version can be found at https://swat.tamu.edu/software/arcswat/. A basic hydrology model of the area can be seen in Pamungkas and Purwitaningsih (2019) and Purwitaningsih and Pamungkas (2017). SWAT analysis also comprises the following four main stages:

1. Re-delineation of catchment areas: Purwitaningsih and Pamungkas (2017) explained the re-delineation process of the Kedurus catchment area in detail. The process produced twenty-seven sub-catchment areas.
2. Defining Hydrologic Response Units (HRUs) based on key hydrological data such as land use, soil type, and slope.
3. Creating a climate generator from the Global Weather Database for SWAT by selecting the measurement location at Perak Station II from 2004 to 2013.
4. Lastly, building a database for simulations: SWAT simulations are carried out for the conditions of the year 2016 and the final year of the detailed spatial plan (2038). The output is water discharge data (streamflow).

The main components of the model are:

1. Climatic data from 2004 to 2013 such as monthly data on rainfall, temperature, humidity, radiation and wind speed. The climatic data is drawn from the global weather database for SWAT (Dile & Srinivasan, 2014; Fuka et al., 2013).
2. Soil type data from the Surabaya Regional Plan 2014-2034 and the Gresik Regional Plan 2011-2031.
3. ALOS PALSAR Digital Elevation Model with a 12.5m x 12.5m cell size derived from www.asf.alaska.edu.
4. Existing land use: Since the Kedurus catchment area is located in two administrative regions, the land use data is collected from both governments (Surabaya City and Gresik Regency). The main source for the existing land use in Surabaya is the Surabaya detailed plan. The authors assessed the draft of this plan during the period of April-July 2018. Since there is no detailed plan for the Kedurus catchment area in Gresik, the study uses the existing land use based on the Gresik Regional Plan 2011-2031.

The effectiveness of the proposed plan is defined as the gap between the current and predicted runoff. Thus, the assessment of the predicted surface runoff uses the data from the planning section of the detailed plan, while the climatic and soil types are considered unchanged from the current situation. The main difference between the current and the predicted situation is the allocated land use based on the spatial plan. Some changes in the infrastructure to reduce flood risk are also considered to be significant. Therefore, assessing the predicted runoff in 2038 will use the data from the planning section of the detailed plan, particularly for data on land use, building regulations, the drainage system, and other infrastructure related to flood reduction.

3. RESULTS

3.1 Current Development in the Kedurus Catchment Area

The Kedurus catchment area is part of the Brantas catchment area and encompasses an area of 7,270.1 ha covering some parts of Surabaya City and Gresik Regency (Purwitaningsih & Pamungkas, 2017). In Surabaya, the catchment covers five districts: Dukuh Pakis, Karangpilang, Lakartsantri, Wiyung and Sambikerep (*Figure 1*). Based on the Surabaya Regional Plan (RTRW) 2014-2034, the catchment area also covers the city's two main developmental areas: West Surabaya and South Surabaya. These areas have experienced rapid growth since 2001.

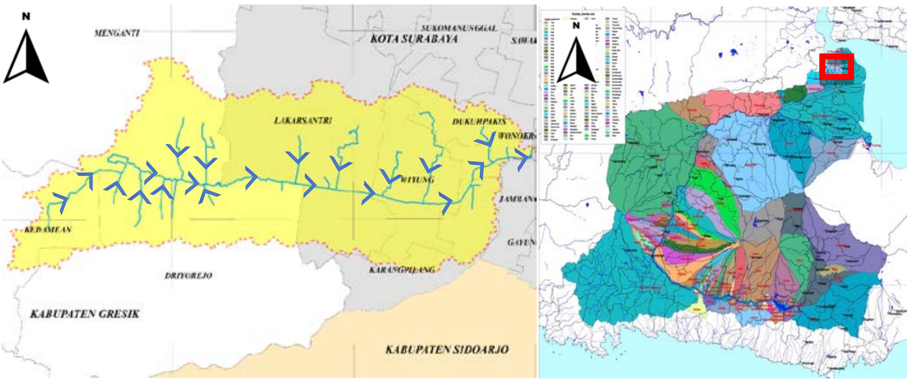

Figure 1. The orientation of the Kedurus catchment area.
A: The Kedurus catchment area with water flow from west to east covers two administrative regions with the eastern part belonging to Gresik Regency and the western part to Surabaya City. B: The location of the Kedurus catchment area (red box) in East Java Province, Indonesia.

Zulkarnain (2016) measured the increase in built-up areas in West and South Surabaya and found 66.56% and 7.79% respectively of land conversion into built-up areas. Residential areas account for the main increase in built-up areas. Conversely, the main decrease is in vegetated land of about 30.88% and 33.79% in West and South Surabaya respectively. Around one-third of the total open space has been converted into built-up areas during the last fifteen years. These changes will increase runoff resulting in higher flood risk in the future as compared to the current situation. *Figure 2* illustrates the land conversion process in Surabaya between 2001 and 2015.

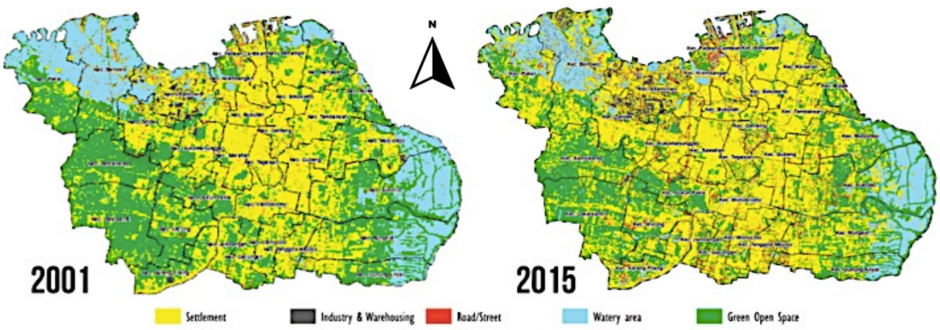

Figure 2. Land conversion in Surabaya between 2001 and 2015 (not to scale)
Source: Zulkarnain (2016)

The Kedurus catchment area experiences some of the fastest growth in Surabaya City. The high overall economic development in Surabaya is one of the reasons for the fast growth in most of the city's precincts. The economic growth in Surabaya is around 6% which is higher than East Java Province (5.5%) and Indonesia (5.02%) (Statistics Indonesia, 2017). The core of the catchment area in Surabaya (Dukuh Pakis, Wiyung, and Lakarsantri districts) experiences a high rate of population growth. Dukuh Pakis (1.33%) and Lakarsantri (2.08%) have higher growth rates than Surabaya's average (0.63%) based on the Surabaya City profile in 2017. The Surabaya part of the catchment area is also a location for new residential developments which is a consequence of Surabaya's urban spillover. The new developments include the residential complexes of Babatan, Pratama, Graha Family, and Royal Residences (*Figure 3*). All these development pressures increase the conversion of non-built-up land to built-up areas. This horizontal development increases surface runoff due to the decreased infiltration rate of rainwater.

Figure 3. Photos illustrating a typical high-income residential complex in the Surabaya part of the catchment area. These complexes are a significant cause of the conversion of open space into built-up areas.
Source: Google Street View, 2018

Figure 4 illustrates the land use in 2014 on the Surabaya side of the catchment area. Residential area (40.96%) is the dominant land use in the area, while the amount of open space is still at a reasonable level of 22.11%. This percentage is still higher than the mandatory 20% based on the Ministry of Public Works Regulation No.05 of 2008. Other land-use types are still limited, such as commercial areas (2.68%), industry (0.04%) and public facilities (3.57%). Furthermore, the primary survey shows a variety of floor area ratios (FAR) and green area ratios (GAR). FAR is roughly around 80% and the GAR ranges from 0% to 10%. The current drainage system also has varying river debit capacities of around 3.50 m^3/s to 756 m^3/s (*Table 1*).

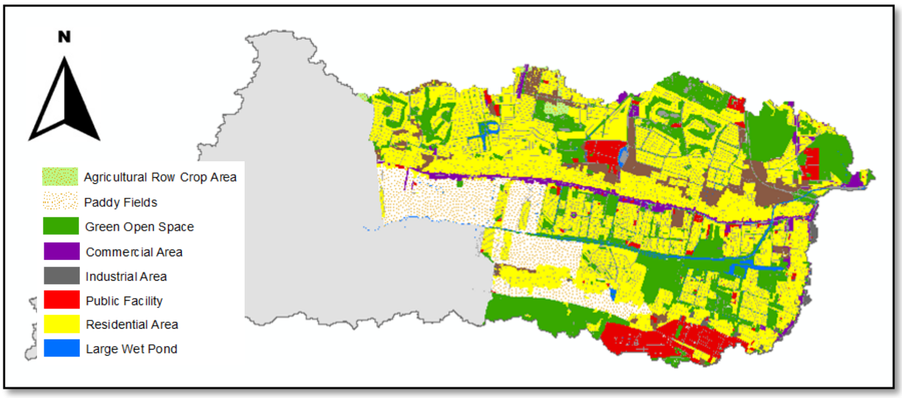

Figure 4. Existing land use in 2014 (not to scale). Grey areas indicate outside Surabaya City, in the catchment areas.
Source: Draft of RDTR 2018-2038

Table 1. River current capacity on Surabaya side of Kedurus catchment area.

No.	Supported Sub-Catchment	Name of River	River Hierarchy	Dimension (m)	Debit Capacity (m3/s)
1	1	River under the highway	Secondary	W= 3.3 ; D= 1.7	50.76
2	2	Kali Kedurus - Singgasana Hotel River Section.	Primary	W= 24.6; D= 2.13	699.00
3	8	Kali Kedurus - Taman Wisata Residential Complex River Section.	Primary	W= 6.5; D= 2.44	3.62
4	11	Wisma Lidah Kulon Channel	Secondary	W= 1.6; D= 1.2	26.54
5	14	Kali Kedurus - River Section under Tol Road.	Primary	W= 15; D= 2.25	295.20
6	15	Kali Kedurus - Prambanan Residence Complex River Section.	Primary	W= 15.7; D= 1.93	3.51
7	16	Prambanan Residence Channel	Secondary	W= 9.6; D= 2.52	432.00
8	17	Kali Kedurus - Prambanan Residence Complex Lane 1 River Section.	Primary	W= 15.7; D= 1.43	64.25
9	18	Lidah Kulon Channel.	Secondary	W= 9.6; D= 2.26	348.61
10	19	Kali Kedurus - School River Section.	Primary	W= 25.1; D= 2.65	308.60
11	20	Babatan Channel.	Secondary	W= 4.6; D= 2.89	102.71
12	21	Kali Kedurus - SMPN 34 River Section.	Primary	W= 37; D= 2.65	415.70
13	22	Kali Wiyung.	Secondary	W= 2.6; D= 1.17	20.63
14	24	Kali Kedurus - Raya Menganti Road River Section.	Primary	W= 29.7; D= 2.11	13.40
15	26	Blok T Channel.	Secondary	W= 25.9; D= 2.36	502.79

Source: Primary survey in 2017
Note: W= width; D= depth

3.2 Current Hydrological Model Outputs in the Catchment Areas

The SWAT simulation results in surface runoff of about 277.48 mm based on the data of the current development in the Kedurus catchment area. This amount of water must be accommodated by the drainage system. Moreover, with an average precipitation of 1,475.9 mm, there are two other types of runoff, lateral flow (2.85 mm) and water that infiltrates shallow aquifers (214.15 mm). The water in the shallow aquifers continues to be discharged into the Kedurus River (with a return flow of 157.52 mm), it recharges the deep aquifer (10.71 mm), and some of the water evaporates (45.16 mm).

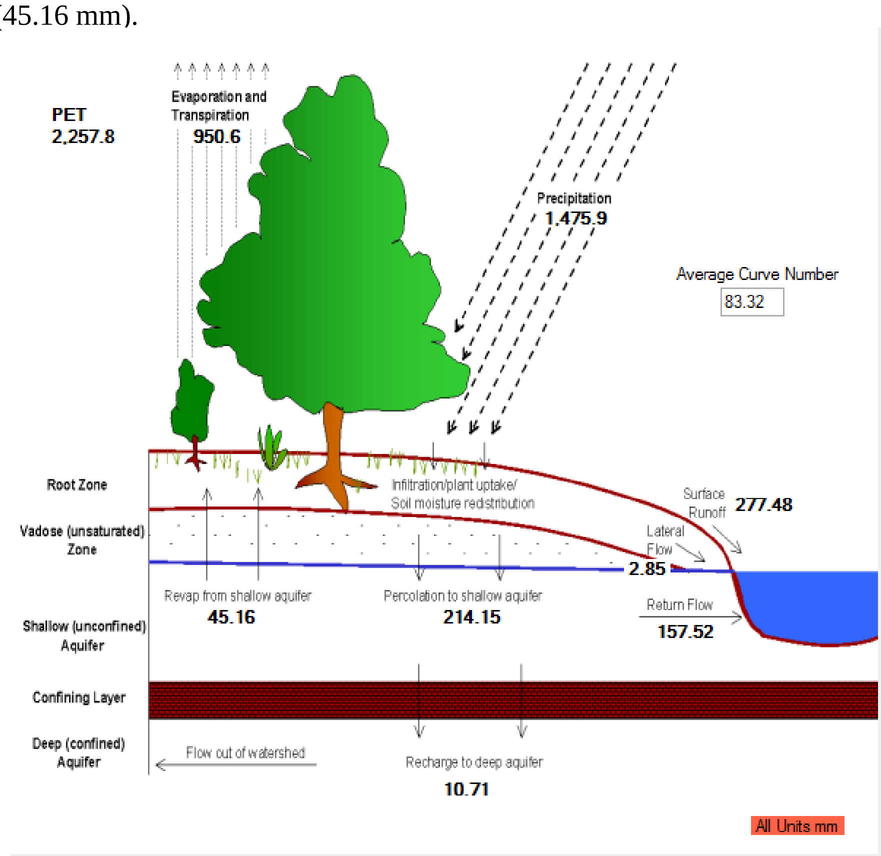

Figure 5. Model output of SWAT for the current situation

The current main strategy for flood control in the city of Surabaya focuses on primary, secondary, and tertiary drainage channels. The main programs are widening existing channels, maintaining the capacity of current channels, and developing new channels. These three actions are considered the grey infrastructure approach. Among the three, maintaining the capacity of current channels is quite challenging. All drainage channels in Surabaya are experiencing siltation due to sedimentation processes. Therefore, maintaining the maximum capacity of the drainage channels is important in this approach. Figure 6 describes the current capacity of key drainage channels in this catchment area. The current drainage system capacity varies from 3.51 m^3/s to 699 m^3/s.

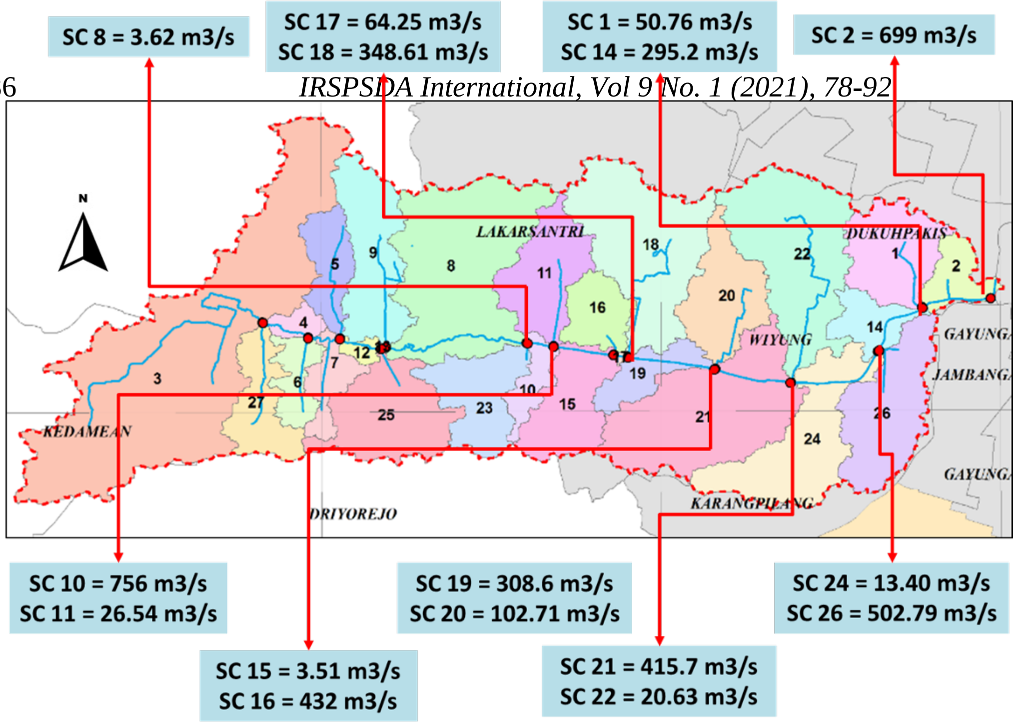

Figure 6. Current drainage system capacity. SC indicates sub-catchment areas. Grey areas indicate outside of the catchment areas, in Surabaya City.

Based on the model, the current drainage capacity is lower than the surface runoff. As a result, flooding occurs in sub-catchment 3 (with a flood volume of 3,470.40 m^3), sub-catchment 8 (with a flood volume of 45,057.60 m^3), sub-catchment 15 (with a flood volume of 73,584 m^3), and in sub-catchment 24 (with a flood volume of 22,176 m^3). Of these flooded sub-catchment areas, sub-catchment areas 15 and 24 are fully located in Surabaya as well as most of sub-catchment 8. Sub-catchment 3 is the only flooded sub-catchment located in Gresik Regency. The highest simulated discharge occurs in sub-catchment 2 (17.04 m^3/s), followed by sub-catchment 14 with a debit of 16.15 m^3/s, and sub-catchment 24 with a debit of 14.94 m^3/s. Most of the sub-catchment areas have a smaller discharge rate than the river capacity except for sub-catchments 8, 15, and 24, which have a larger discharge rate than the river capacity. The measuring point of the river capacity of those sub-catchments is in the secondary channel.

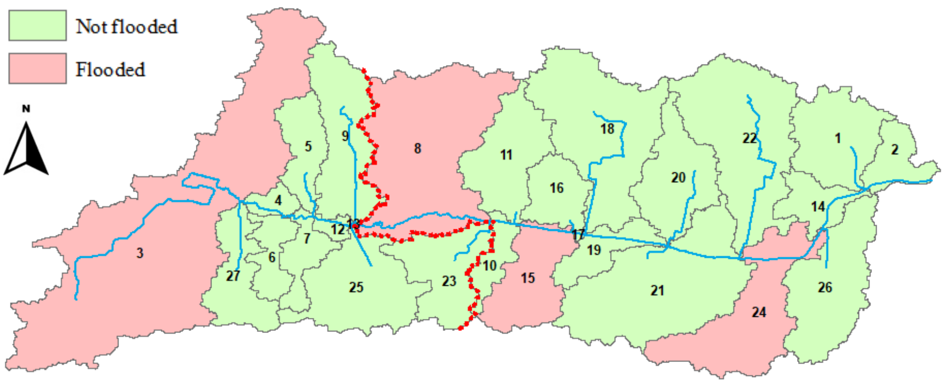

Figure 7. Flooded sub-catchment areas in the current situation

3.3 Model Modification to Accommodate the Future Land Use Plan

To be able to assess the effectiveness of the detailed plan, the above model requires modifying. The draft of the detailed plan leads to the following four main changes related to flood reduction in the area:

1. Land-use allocation: Based on the plan (*Figure 7*), the main change is the total land conversion of 1,027.04 ha from non-built-up to built-up areas. The largest conversion of about 158.32 ha occurs in sub-catchment 21 while the smallest conversion of about 1.74 ha occurs in sub-catchment 17. Both sub-catchment areas are located in Surabaya. In sub-catchment areas 8, 15 and 24, the predicted land-use conversion will be 150.13 ha, 70.57 ha, and 64.84 ha respectively. Sub-catchment 8 will experience the second highest land conversion on the Surabaya side of the Kedurus catchment area.

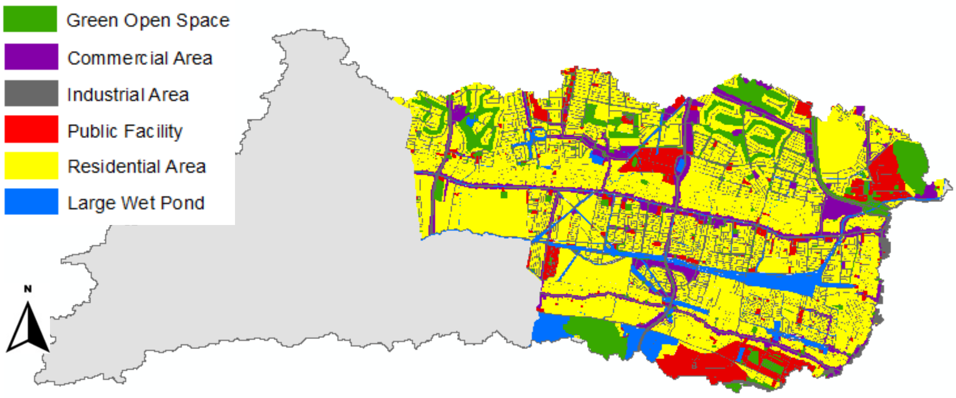

Figure 8. Land use plan
Source: Draft of Surabaya Detailed Plan 2018-2038 (not to scale). Grey areas indicate outside Surabaya City, in the catchment areas.

2. Building regulations: The detailed plan stipulates that the FAR is 80% and the GAR 10%. Since there are no strict regulations in place, in reality, the FAR can be higher than 80%, especially when accommodating supporting facilities on a land parcel, such as carports. Therefore, the built-up area within a parcel could be up to at least 90% in the current situation. It is difficult to enforce the implementation of 80% FAR. For the green open space, the detailed plan has permitted 10% of FAR for built-up areas. Nevertheless, this regulation cannot be accommodated in the software since green open space is assumed to be 100% green without buildings. The effect of this regulation on the model is negligible as, in fact, most green open space in this case study is still free of buildings. Therefore, the green open space is assumed to have a GAR of 100% in the predicted model.

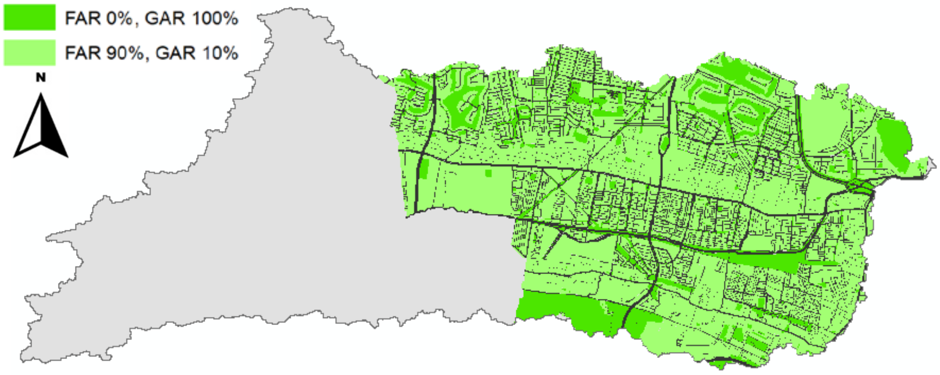

Figure 9. Building Regulations in the Area (not to scale). Grey areas indicate outside Surabaya City, in the catchment areas.

3. Drainage system: As stipulated in the detailed plan, the main drainage system will have an increased capacity. Improving the drainage system is still the key approach of Surabaya City in reducing flooding. A comparison between the current river dimensions in 2017 and the plan shows that most river dimensions are planned to increase, particularly the main river (Kali Kedurus). However, due to resource limitations, including financial limitations, Surabaya plans to increase the drainage capacity only in selected sub-catchment areas. The main target of the plan is a 55% increase of river dimensions for selected sub-catchment areas. In particular, sub-catchment areas 11, 15 and 17 are planned to more than double their capacity as compared to the current situation. *Table 2* compares the drainage capacity for the selected sub-catchment areas in Surabaya between the two timeframes.

Table 2. Comparison of current and planned drainage capacity.

No. of Sub-Catchment	Current Drainage Capacity (M^3/S)	Planned Drainage Capacity (M^3/S)	Change in Drainage Capacity (%)
2	699	1,182.23	69%
11	26.54	67.02	153%
15	3.51	7.41	111%
17	64.25	142.62	122%
18	348.61	352.36	1%
19	308.6	442.93	44%
20	102.71	105.32	3%
21	415.7	442.93	7%
22	20.63	22.66	10%
24	13.4	17.06	27%
		Average	55%

Source: Modified from the primary survey and the detailed plan
Note: Current width data comes from the primary survey conducted in 2017
Planned width data comes from the draft Surabaya Detailed Plan 2018-2038

4. Infrastructure investments related to flood reduction in the detailed plan: There are two main infrastructures related to floods in Surabaya, large wet ponds and pumping stations. Unfortunately, the pumping stations cannot be applied in the SWAT software. Moreover, pumping is also considered ineffective for several reasons. Notably, Surabaya has experienced various problems with pumping stations, for example, pumping stations are manually operated resulting in high inundation in major parts of Surabaya in

cases of unpredicted heavy rainfall such, as in the Tenggilis Area (Surya Online, 2013); pumps have been found missing (Cahyono, 2017); the pumped water will flow back if the sea level rises because of high tide or climate change (Cahyono, 2017); and the pumps are ineffective in cases of extreme rainfall since many drainage systems are already at full capacity (Perdana, 2016). Therefore, this paper only considers large wet ponds as flood-related infrastructure. Based on the land use plan, in 2038, Surabaya will have around 259.90 ha of wet ponds. This is an increase of 236.38 ha compared to the current situation of only 23.52 ha based on the GIS map calculation of the existing land use map. Figure 7 shows the planned land use based on the changes above.

3.4 Future Hydrological Model Outputs in the Catchment Area as a Consequence of the Surabaya Detailed Plan 2018-2038

A simulation of the detailed plan shows an increase in potential flooding in Surabaya (*Figure 8*) compared to the current situation (*Figure 3*). The model shows a 22.5% increase in surface runoff when applying the same precipitation (1,475.9 mm). Moreover, the infiltration rate decreases resulting in a lower amount of water for lateral flow (2.58 mm) and shallow aquifers (175.78 mm). The low infiltration rate will decrease the amount of water to recharge groundwater. *Figure 8* illustrates that both models have the same precipitation value but the future scenario shows an increase in surface runoff and a decreased infiltration to the aquifer (groundwater). Therefore, the comparison of the current and future models indicates that the future spatial plan will increase the probability of flooding, thus increasing future hazards for Surabaya.

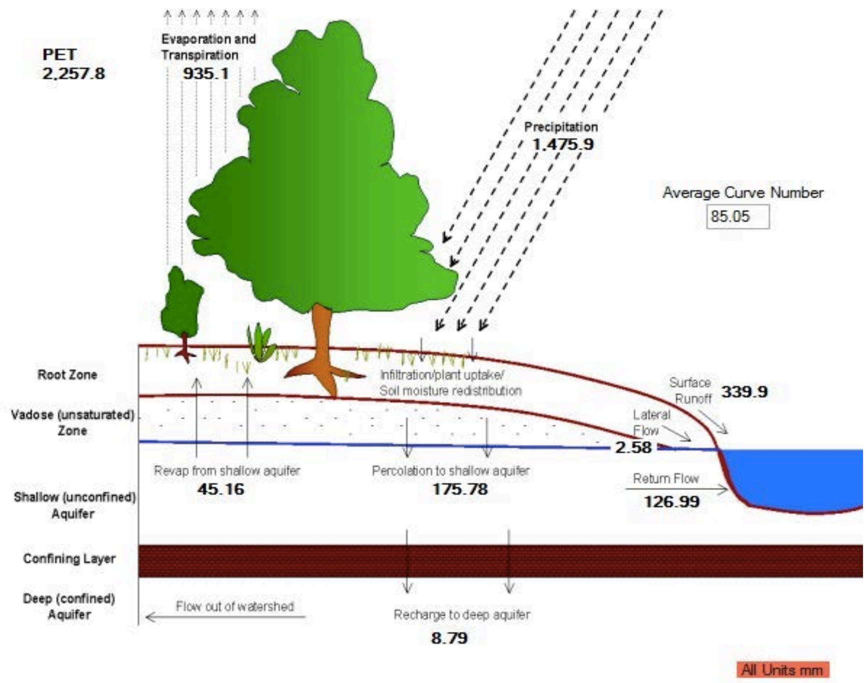

Figure 10. Model Output of SWAT for the future situation based on the detailed plan

In the planned situation, sub-catchment areas 3, 8 and 15 still experience flooding. Based on the plan, sub-catchment area 24 is no longer flooded because of the successful strategy of constructing wet ponds and improving the drainage system. For sub-catchment areas 3 and 15, the flooding will decrease by about 13% and 72% respectively. A high increase in drainage capacity in sub-catchment area 15 will effectively decrease flooding. Unfortunately, the floods in sub-catchment 8 will increase by 3% resulting in a higher flood volume in the future. A high land conversion within the area increases the potential flooding despite the government's plan to build a wet pond within the sub-catchment area.

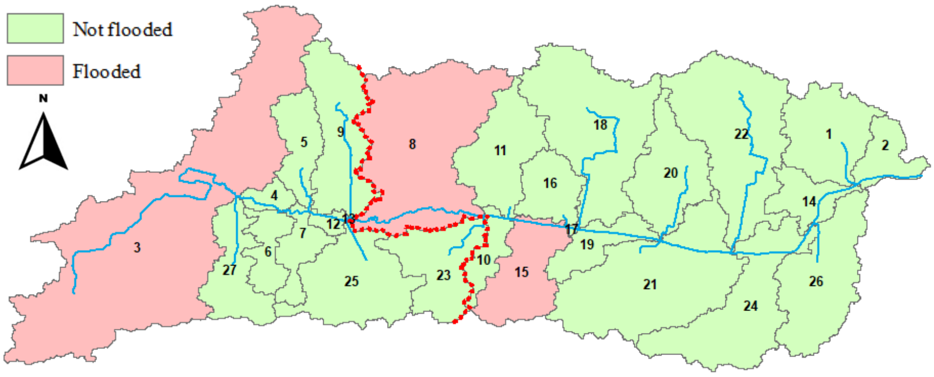

Figure 11. Projected flooded sub-catchment areas based on the hydrological model (not to scale)

The major cause of the increased risk of flooding in the Kedurus catchment area is the high conversion rate from open space to residential areas. The open space could be in the form of paddy fields or bare land. The construction of wet ponds or increasing the drainage capacity is still insufficient to accommodate the flood volume caused by the land conversion. Nevertheless, the plan has a positive impact on Gresik Regency. Despite having no changes in its land use, building regulations, drainage system, and infrastructure to reduce flood risk in Gresik, the high increase in Surabaya's flood risk-reducing infrastructure (building large wet ponds and increasing the drainage capacity) decreased the sub-catchment areas susceptibility to flooding in Gresik Regency (by around 12%). The infrastructure investments in Surabaya will speed up the discharge process from the upstream part of the catchment area (sub-catchment 3) in Gresik Regency to downstream Surabaya.

4. CONCLUSION

Flash flooding occurs in the administrative regions of Surabaya City and Gresik Municipality of the Kedurus catchment area. One of the instruments to reduce flooding is the spatial plan which is ultimately aimed at creating a low-risk city. The Detailed Spatial Plan (RDTR) comprises four types of spatial regulations related to flood reduction: the land use plan, building regulations, the drainage system, and investments in infrastructure related to flood risk reduction. These four instruments are aimed at reducing flooding over the next twenty years.

Simulations for both current and future scenarios based on the detailed plan show a lower risk for Surabaya. A decrease in flooding occurs in all flooded sub-catchment areas except sub-catchment 8. The strategy of increasing drainage capacity and constructing wet ponds in Surabaya to significantly discharge and accommodate the runoff makes predicted flash flooding lower impact than what is happening currently.

Surabaya's ambitious program of increasing the drainage capacity and constructing wet ponds could put the city at high risk; although Surabaya's infrastructure approach is effective, its implementation is still questionable due to budget limitations and challenges in the land acquisition process. Moreover, the development pressure, as reflected by land-use change, will further increase the amount of runoff in Surabaya. The increasing projected surface runoff based on modelling indicates a higher probability of flood hazards in the future. If the construction of grey infrastructure for flood reduction does not happen according to the plan, Surabaya will face catastrophic flooding. In addition, future rainfall patterns influenced by climate change can exacerbate flooding in the future. This implies that Surabaya's approach in the detailed spatial plan is still insufficient in protecting the city from flooding, specifically parts of the city within the Kedurus catchment area.

Surabaya needs to expand its range of programs into accommodating surface runoff and/or increasing the infiltration rate. An approach such as a water sensitive city (WSC) could avoid increasing the risk of flooding in the future by decreasing future runoff. In implementing the WSC concept, Surabaya should not only rely on drainage and wet ponds, rather, the city can provide other green infrastructure such as rain barrels, buffer strips, green roofs, permeable paving, and long-term storage. These types of green infrastructure will decrease surface runoff by increasing the infiltration rate or by temporarily accommodating runoff. These types of green infrastructure are perceived as a sustainable approach to reducing flood risk. Furthermore, slowing down the conversion rate is one of the greatest challenges for Surabaya. Concepts such as the compact city, walkable city, and vertical living are some options to change the pattern of Surabaya's development in the future and can be classified as low impact development to flooding issues. The resulting changed development pattern will lower the rate of land conversion and prevent an increase in runoff. This low impact development can help reduce surface water runoff naturally and effectively. Lastly, Surabaya can prevent flash flooding by discharging surface runoff via the increased capacity of current channels, decreasing runoff with wet ponds, buffer strips, permeable pavement and green roofs, and accommodating runoff using rain barrels and long-term storage.

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